10/534063

JC20 Rec'd PCT/PTO 06 MAY 2005

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re patent application of

Walter DEMUTH et al.

Corres. to PCT/EP2003/012440

For: HEAT EXCHANGER

VERIFICATION OF A TRANSLATION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

I, Charles Edward SITCH BA,

Deputy Managing Director of RWS Group Ltd UK Translation Division, of Europa House, Marsham Way, Gerrards Cross, Buckinghamshire, England declare:

That the translator responsible for the attached translation is familiar with both the German and the English language, and that, to the best of RWS Group Ltd knowledge and belief, the English translation of International Application No. PCT/EP2003/012440 is a true, faithful and exact translation of the corresponding German language paper.

I further declare that all the statements made in this declaration of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful, false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful, false statements may jeopardize the validity of legal decisions of any nature based on them

Date: April 18, 2005

Name: Charles Edward SITCH

Deputy Managing Director UK Translation Division

For and on behalf of RWS Group Ltd

HEAT EXCHANGER

Description

The invention relates to an apparatus for heat exchange, in particular for use in air-conditioning systems and especially for use in air-conditioning systems which, as refrigerant, have a fluid which has, for example, at least carbon dioxide as a constituent.

Such apparatuses for heat exchange are used, for example, to cool or condense refrigerants.

The invention and the technical problems on which it is based will be described below with reference to an example of a motor vehicle air-conditioning system. However, it should be noted that the apparatus according to the invention is also suitable for other intended applications.

The invention also relates to a process for producing an apparatus for heat exchange.

The prior art has disclosed air-conditioning systems in motor vehicles. These air-conditioning systems use a refrigerant which is used to cool air for the vehicle interior. Examples of refrigerants of this type include chlorofluorocarbons. However, air-conditioning systems which are operated with refrigerants of this type have the drawback of causing a significant increase in the fuel consumption of a motor vehicle. Furthermore, these conventional refrigerants have a very high greenhouse gas potential and consequently the use of these refrigerants also increases the environmental problems caused by the greenhouse effect. For this reason, in recent times, a further refrigerant, namely carbon dioxide (CO_2), has been used. Compared to the refrigerants referred to above, carbon dioxide has a

considerably lower greenhouse gas potential. Furthermore, carbon dioxide does not cause any damage to the ozone layer, since it is a natural gas. Finally, the use of carbon dioxide as refrigerant also makes it possible to reduce the fuel consumption of the motor vehicle.

However, when carbon dioxide is used as refrigerant, very high pressures in the range of up to more than 130 bar have to be produced. The pressure loading on individual components of an air-conditioning system therefore rises significantly, thus requiring higher stability.

The invention is therefore based on the object of providing an apparatus for heat exchange which is improved in comparison to the prior art.

According to the invention, the object is achieved by the subject matter of main claim 1. Advantageous refinements form the subject matter of the subclaims.

In one embodiment, an apparatus for heat exchange, in particular for use in motor vehicles and especially for use in motor vehicle air-conditioning systems which, as refrigerant, have a fluid which comprises at least one constituent selected from a group of gases consisting in particular of carbon dioxide, nitrogen, oxygen, air, ammonia, hydrocarbons, in particular methane, propane, n-butane, and liquids, in particular water, fluids, brines, etc., has a feed line and a discharge line in order to introduce the fluid into the apparatus and to remove the fluid from the apparatus. In one particularly preferred embodiment, the refrigerant used is carbon dioxide, which is distinguished by its physical and chemical properties, such as, for example, noncombustibility.

Furthermore, the apparatus according to the invention for heat exchange has at least two heat exchanger units, each of these heat exchanger units having at least one distribution space and one collection space and at least one throughflow device, with it being possible for the fluid to flow between the distribution and collection spaces through the throughflow device.

Furthermore, each of these heat exchanger units has at least one separating device which divides at least one distribution or collection space into two subspaces.

The apparatus also has a flow connection device which connects the heat exchanger units to one another in such a manner that the refrigerant can flow between the heat exchanger units, with the flow cross sections or the flow cross section totals upstream and downstream of the flow connection device assuming a predetermined ratio to one another. This ratio depends in particular on the position of the flow connection device.

In a further preferred embodiment, the throughflow device has at least one first end-side flow connection section, through which the fluid enters the throughflow device or leaves the throughflow device.

Furthermore, a second end-side flow connection section is provided, through which the fluid leaves the throughflow device or enters the throughflow device. The first flow connection section and the second flow connection section are flow-connected to each other by at least one tube section.

In the context of the present invention, the term "flow-connected" is to be understood as meaning that a fluid can flow between two flow-connected sections.

In a further preferred embodiment, the tube section has at least one straight section, and is linear (what does this mean?) preferably along its entire length. However, in addition to straight sections, the tube section may also have one or more curved sections.

In one particularly preferred embodiment, at least one of said end-side flow connection sections is twisted at least once. In this context, the term "twisting" is to be understood as meaning that a component is rotated or twisted through a defined, predetermined angle along its longitudinal direction. In this case, the central axis may be offset.

In a further particularly preferred embodiment, the apparatus for heat exchange has in its entirety or at least the throughflow device, as a component of the apparatus, has a preferably gaseous medium, in particular air, flowing around it.

Within the meaning of the present invention, a collection space is to be understood as meaning a device which is suitable for collecting medium supplied to it from at least one component, preferably a plurality of components. The distribution space is used to distribute a fluid which is introduced into it to at least one, preferably a plurality of, devices or throughflow devices.

In a further preferred embodiment, the throughflow device has at least one flow passage, preferably a multiplicity of flow passages, for passing on the refrigerant, and preferably has a cross section in the form of a flat tube.

In the context of the present invention, the term in the form of a flat tube is to be understood as meaning that the cross section is substantially in the shape of

a rectangle or ellipse, with the longer side of this rectangle being longer than the shorter side or the longer semi-axis being longer than the shorter semi-axis.

According to a preferred embodiment, the transitions between the sides of the cross section are rounded.

In a further particularly preferred embodiment, a plurality of heat exchanger units are provided, which are in each case connected to flow connection devices. The plurality of heat exchanger units are preferably connected in pairs in each case by flow connection devices.

In this case, the number of heat exchanger units is particularly preferably n, and the number of flow connection devices n-1. However, it is also possible to provide a plurality of flow connection devices between the individual heat exchanger units.

In a further preferred embodiment, the feed line and the discharge line for the refrigerant are arranged at two different distribution or collection spaces.

In a particularly preferred embodiment, the feed line and the discharge line for the refrigerant extend along the longitudinal direction of the distribution and collection spaces at which they are arranged.

In a further particularly preferred embodiment, a frame device is provided which connects the individual heat exchanger units to one another nonpositively, positively and/or cohesively.

In a preferred embodiment, the distribution space and/or the collection space have receiving devices or lead-through devices, the internal cross section of the

receiving devices substantially corresponding to the external cross section of the throughflow device. In this case, the external cross section of the throughflow device is particularly preferably slightly smaller than the internal cross section of the receiving devices, so that the throughflow device, preferably a plurality of throughflow devices, can be pushed into the individual receiving devices or can be pushed through them. The receiving device may also be designed as a lead-through device, so that the throughflow device is pushed through the receiving device into the collection and/or distribution space. The receiving device may also be designed in such a manner that a plurality of flat tubes can be accommodated therein.

In a further preferred embodiment, the receiving devices are substantially rectangular or elliptical in form, with the longer side of these substantially rectangular or elliptical receiving devices being arranged at a predetermined angle with respect to the longitudinal direction of the distribution and collection device.

In this case, the longitudinal direction of the distribution/collection device is to be understood as meaning the direction in which the distribution/collection space substantially extends.

In a further preferred embodiment, the magnitude of this predetermined angle between the longitudinal direction of the distribution/collection space is between 0 and 90 degrees, preferably between 0 and 45 degrees, and particularly preferably between 0 and 10 degrees. In this context, a rotation of the receiving device in the clockwise direction with respect to the longitudinal direction is indicated by a positive angle.

In a further preferred embodiment, a plurality of throughflow devices are arranged substantially parallel to one another. In this context, the term parallel arrangement is to be understood as meaning that the flattened part in each case of the throughflow device which is in the form of a flat tube is substantially parallel to the flattened part of the other throughflow devices. In a further preferred embodiment, cooling ribs which promote heat exchange with the air flowing through or around are provided between the throughflow devices.

Devices for heat exchange, such as, for example, cooling ribs, vanes or slats, are particularly preferably provided between the individual throughflow devices.

In a further preferred embodiment, the flow connection device is arranged at a predetermined angle with respect to the longitudinal direction of the distribution or collection spaces. In this case, this predetermined angle is in the region of between 0 and 90 degrees, preferably between 0 to 45 degrees, and particularly preferably in the region of approximately 30 degrees.

The effect achieved by the use of the separating devices and the flow connection device is that the refrigerant does not immediately expand along the entire length of the apparatus, but rather that the refrigerant flows through some sections of and consecutively through the individual throughflow devices, which will be described in more detail below.

In one particularly advantageous embodiment, the separating device and the flow connection device are arranged in such a manner that medium flows firstly

through a first section, remote from the air flowing through, then through a second section, remote from the air flowing through, then through a first section facing the air flowing through, and then through the second section facing the air flowing through. As an alternative, it is also possible to allow the refrigerant to flow firstly through the sections remote from the air and then through the sections facing the air.

This embodiment is particularly advantageous if the fluid temperature experiences a difference in temperature (temperature response) along the flow path, the fluid temperature decreasing along the flow path in the case of a gas cooler which is operated in particular with a fluid (for example CO_2) in a super-critical range. By virtue of the arrangement of the feed line on that part of the heat exchanger which is remote from the air and the arrangement of the discharge line on that part of the heat exchanger which faces the air, it is ensured that over the entire flow path of the fluid - from the inlet to the outlet - there is an optimized operative difference in temperature between the fluid flowing through the heat exchanger and the air flow. In addition, this arrangement enables all of the tubes on the output side to be directly in contact with the cooler air flow.

In a further embodiment, the use of a plurality of separating devices in the individual distribution and collection spaces results in the formation of a plurality of the abovementioned sections, and the refrigerant can thus be conducted through the connections more frequently in the manner of a cross-countercurrent. Furthermore, it is also possible to provide a plurality of flow connection devices between two heat exchanger units in order thereby to conduct

the refrigerant to and fro between the individual heat exchanger units more frequently.

In a further preferred embodiment, the throughflow device is produced from at least one material selected from a group of materials consisting of metals, in particular aluminum, manganese, silicon, magnesium, iron, brass, copper, tin, zinc, titanium, chromium, molybdenum, vanadium, and alloys thereof, in particular wrought aluminum alloys with a silicon content of from 0 to 0.7% and a magnesium content of between 0.0 and 1%, preferably between 0.0% and 0.5%, and particularly preferably between 0.1% and 0.4%, preferably EN-AW 3003, EN-AW 3102, EN-AW 6060 and EN-AW 1100, plastics, fiber-reinforced plastics, composite materials, etc.

In a further embodiment, more than one, preferably heat exchanger units are provided and are thermally separated from one another.

The term thermal separation is to be understood as meaning a state which completely or at least substantially prevents heat transfer between the components involved, i.e., for example, two heat exchanger units. In a preferred embodiment, the thermal separation of the heat exchanger units is achieved by the distribution space and the collection space being spaced apart from one another, so that an air gap is formed between the spaces.

In a further embodiment, the heat exchanger units are held spaced apart by means of a frame device. It is also possible for bridge-like connections to be provided between the heat exchanger units in order to hold the latter spaced apart.

In a further particularly preferred embodiment, a material which effects thermal separation between the distribution space and the collection space is arranged between the heat exchanger units, and the distribution space and the collection space are cohesively connected to one another by means of this material.

The invention also relates to a device for exchanging heat, in particular for motor vehicle air-conditioning systems, having air flow paths, air flow control elements, at least one air delivery device and a housing which is suitable for receiving at least one apparatus for heat exchange and within which such an apparatus for heat exchange is arranged.

The invention preferably relates to a device for exchanging heat, in particular for motor vehicle air-conditioning systems, having at least one evaporator, a compressor, an expansion valve, a collector and at least one apparatus for heat exchange.

The invention is explained in more detail in the exemplary embodiment below with reference to the associated drawings, in which:

fig. 1 diagrammatically depicts an apparatus for heat exchange in accordance with the invention;

fig. 2 diagrammatically depicts a throughflow device for the apparatus according to the invention;

fig. 3 shows a diagrammatic plan view of a flow connection section on one side for an apparatus for heat exchange;

fig. 4 diagrammatically depicts a collection space or a distribution space for an apparatus for heat

exchange in accordance with the present invention;

fig. 4a shows an illustration on line A-A in fig. 4;

fig. 5 shows a side view of the illustration shown in figure 1;

fig. 6 diagrammatically depicts the flow directions in the apparatus for heat exchange from fig. 5;

fig. 7 shows a perspective illustration of a flow connection device according to the invention;

fig. 7a shows a further illustration of the flow connection device shown in fig. 7; and

fig. 7b shows a further illustration of the flow connection device shown in fig. 7.

Fig. 1 shows an illustration of an apparatus for heat exchange in accordance with the present invention. The apparatus has a feed line 1 and a discharge line 2. The feed line 1 opens into a distribution space or collection space 4b in such a manner that it is flow-connected to this space. A distribution space or collection space is to be understood as meaning a volume element substantially delimited in the longitudinal direction. This volume element may extend over the entire length l of the apparatus but may also be of a shorter length, for example if separating devices are provided. Reference numeral 7 indicates a throughflow device, through which a fluid can flow. It is preferable for a plurality of these throughflow devices 7, 7′, 7″ to be arranged in the apparatus for heat exchange. Cooling ribs 10 are provided between these throughflow devices.

The main flow direction of the air flowing through the apparatus or of the air flowing around the apparatus is substantially perpendicular to the flow surface of the fluid in fig. 1 and is indicated by way of example by the arrows P.

These cooling ribs preferably have gills (not shown in the illustration) which further promote heat exchange with the air flowing around them, in particular by producing turbulences. The density of the cooling ribs is 10 to 150 ribs per decimeter, preferably 45 to 100 ribs per decimeter, and particularly preferably 50 to 95 ribs per decimeter.

The length of the gills is from 1 mm to 20 mm, preferably between 2 mm and 15 mm, and particularly preferably from 3.5 mm to 12 mm. The width of the slat slots is between 0.05 mm and 0.5 mm, preferably between 0.1 mm and 0.4 mm, and particularly preferably between 0.2 mm and 0.3 mm.

In the illustration, the distribution or collection space 4b, the distribution or collection space 5b and the throughflow device 7 or throughflow devices 7 connecting these two distribution or collection spaces form a heat exchanger unit. In the figure shown, there are therefore two heat exchanger units. In this case, the heat exchanger units may each have their own cooling ribs or common cooling ribs.

Reference numeral 11 denotes a frame device which can at least partially be connected positively, nonpositively and/or cohesively to the collection space and/or the distribution space. Reference numeral 13 refers to a throughflow connection device which brings two of the distribution or collection spaces into flow connection.

(In the context of the present invention, identical in height is to be understood as meaning that the feed line and the discharge line are arranged along a certain direction, here at the substantially identical height h. Substantially identical in height is to be understood as meaning that the distance between the feed line and the discharge line along the direction h is smaller than the height h of the apparatus, is preferably smaller than half of the height h of the apparatus, and is particularly preferably smaller than 1/10 of the length of the device.)

The distribution or collection spaces 4b and 5b are flow-connected to one another by means of at least one, preferably a plurality of, throughflow devices 7. The throughflow device has a cross section which is substantially in the form of a flat tube, and a flow passage or a multiplicity of flow passages for passing on the refrigerant. The individual flow passages are in this case substantially circular or elliptical in cross section.

The height of the individual passages is between 0.2 mm and 3 mm, preferably between 0.5 mm and 2 mm, and particularly preferably between 0.6 mm and 1.8 mm.

The hydraulic diameter is between 0.1 mm and 3 mm, preferably between 0.4 mm and 2 mm, and particularly preferably between 0.6 mm and 1.8 mm.

The distance between the individual throughflow devices along the direction l in fig. 1 is between 2 mm and 30 mm, preferably between 4 mm and 20 mm, and particularly preferably between 6 mm and 14 mm.

Fig. 2 diagrammatically depicts a throughflow device for an apparatus for heat exchange in accordance with the present invention.

Reference numerals 23 and 23′ denote a first and second end-side flow connection section. Reference numeral 26 denotes a tube section of the throughflow device. The end-side flow connection section 23 and the end-side flow connection section 23′ are, as apparent from the illustration, in each case twisted once. In the illustration present here, there is a twisting through a twisting angle of 90 degrees. In principle, however, twisting angles of 0 to 90 degrees in both directions are conceivable. In fig. 3, the two flow connection sections are twisted in the same direction.

However, it is also possible for the twisting to be carried out in different directions.

The width b of the throughflow device is between 4 mm and 20 mm, preferably between 5 mm and 12 mm and, particularly preferably, between 6 mm and 9 mm. The thickness d of the throughflow device is between 1 mm and 3 mm, preferably between 1.2 mm and 2.2 mm, and particularly preferably between 1.5 mm and 2 mm.

Figure 3 diagrammatically depicts the cross section through the throughflow device 7 in the region of an end-side flow connection section 23. In this case, the throughflow device illustrated has a plurality of flow passages 27.

Furthermore, figure 3 serves to illustrate the twisting. In the example shown here, the throughflow device is twisted through 90° in the counterclockwise direction in the direction of the positive z axis, i.e. is rotated through a twisting angle β of -90°. By this definition, the twists of the two end-side flow connection sections 23 and 23′ shown in the figure have a twisting angle with a magnitude of 90° and a negative sign of -90°.

Figure 4 diagrammatically depicts a detail of a distribution or collection space. The distribution or collection space has a multiplicity of receiving devices 31 and 31′. These receiving devices are used to receive and lead through the throughflow device 7. In this case, the internal diameter of these lead-through devices substantially corresponds to the external cross section of the throughflow device 7 at the end thereof and is preferably slightly greater. During production, the end sections of the throughflow device are pushed into the receiving devices 31 and 31′ or are pushed through them. The receiving devices and the throughflow devices are then connected fluid-tightly, for example by means of solder, adhesive or the like.

The connection between the throughflow devices and the receiving devices of the collection or distribution space affords the advantage that it is possible to absorb even the high pressures of, for example, up to approx. 400 bar which are required in carbon dioxide coolers, and the flow paths are still gastight and/or liquid-tight even at these high pressures.

In a preferred embodiment, the depth of insertion of the throughflow devices into the collection or distribution space is limited by the twisting of the end-side flow connection section. However, it is also possible for the throughflow devices to be pushed in until the tubes strike against the boundary walls of the distribution or collection space. The depth of insertion is dependent among other things on the manufacturing process, material thickness, predetermined tolerances, etc. The depth of insertion is normally between 1 mm and 25 mm, preferably between 2 mm and 15 mm, and particularly preferably between 3 mm and 10 mm.

The individual receiving devices 31 and 31′ are arranged along the longitudinal direction l of the receiving space and/or the collection space, i.e. their longitudinal direction, which is indicated by the dashed section g, and includes an angle of a magnitude of less than 10 degrees, preferably substantially 0°, with the longitudinal direction l, i.e. is parallel. However, it is also possible for the receiving devices to be arranged at a different angle of up to 90° with respect to the longitudinal direction.

Fig. 4a shows a section from fig. 4 on line A-A′. Reference numerals 35 and 35′ denote the clamping walls which are used for clamping in the flow connection section. Reference numeral 31 shows the receiving device, which is illustrated in the form of a gap in this sectional representation. As can be seen from fig. 4a, the flow connection section has an approximately Ω-shaped cross section.

Fig. 5 shows a side view of the apparatus for heat exchange in accordance with the present invention. Reference numerals 4a and 4b denote two collection and distribution spaces which are part of two different heat exchanger units. In a preferred embodiment, the two collection and distribution spaces do not directly touch one another but rather are spaced apart from one another, as indicated by reference numeral 8. Reference numerals 1 and 2 refer to a feed line and a discharge line for the refrigerant. However, it is conceivable for the two heat exchanger units to use a common corrugated rib.

In a preferred embodiment, a flow connection of the collection space to the distribution space takes place by means of the web- or bridge-like flow connection device 13.

In this context, web- or bridge-like is to be understood as meaning that the flow connection does not come about exclusively within a distribution or collection device but rather substantially outside the same, for example, in fig. 5, it runs above the same.

In addition, separating devices 13a and 13b are provided, which divide the distribution or collection spaces 4a and 4b into two separate subspaces a and b or c and d in each case. The length of the subspace a is preferably smaller than the length of the subspace c and/or greater than or equal to the length of the subspace d. The length of the subspace b is preferably smaller than or equal to the length of the subspace c. The length of the subspace d is preferably smaller than the lengths of the subspaces b and/or c.

As an alternative, it is, however, possible for the flow connection device 13 to also be combined with the separating devices 13a and 13b and to be pushed into provided slots in the distribution or collection spaces 4a and 4b. In this case, the separating device is preferably soldered or welded to the distribution or collection space or is connected fluid-tightly to the surroundings in some other way.

Fig. 7 shows a perspective illustration of a combined flow connection device/separating device. In this case, reference numerals 13a and 13b refer to the separating elements of the device, and reference numeral 41 denotes a flow connection opening.

Figs 7a and 7b show further views of the combined flow connection device/separating devices shown in fig. 7.

With reference to figures 5 and 6, the flow paths in the apparatus for heat exchange will be explained below in accordance with this embodiment.

The refrigerant first of all passes via the feed line 1 into the space section a of the distribution or collection space 4b. It can extend there along the longitudinal direction 1 of the distribution or collection space 4b as far as the separating device 13b. From there, the refrigerant flows downward via the throughflow devices 7, 7′, 7′′ ... (not shown), i.e. onto the plane of the sheet in the drawing, which is illustrated by the x symbols. In the arrow diagram shown in fig. 4, this is illustrated by the solid, downwardly pointing arrows in the right part of the drawing.

The lower distribution or collection space 5b does not have a separating device, and so the refrigerant can extend here along the entire length thereof. In this case, the right part of this space therefore acts as a collection space and the left part as a distribution space. This is expressed in fig. 6 by the fact that the line symbolizing the distribution or collection space 5b is not depicted in interrupted form.

From the left section of the lower distribution or collection space 5b, the refrigerant flows upward again through the throughflow devices, which is symbolized by the solid, upwardly directed arrows on the left side of fig. 4. The refrigerant passes into the section denoted by b in fig. 5. This is indicated in the figure by the symbols provided with the dot.

From the subspace b, the refrigerant flows via the flow connection device 13 into the subspace, denoted by c, of the distribution and collection space 4a. The refrigerant passes via the throughflow devices into the lower distribution/collection space 5a (shown in fig. 6), i.e. the refrigerant flows in figure 5 in a direction perpendicular with respect to the plane of

the sheet, which is illustrated by the x symbols in fig. 5 and by the downwardly directed, dashed arrows in fig. 6. In the lower distribution/collection space, the refrigerant again extends along the entire length thereof and finally passes again via the throughflow devices into the section d of the distribution and collection space 4a. From there, the refrigerant flows out of the apparatus via the discharge line 2.

The effect achieved by this construction is that the refrigerant firstly flows through substantially all of the throughflow devices of a heat exchanger unit and subsequently through substantially all of the throughflow devices of the second heat exchanger unit. The effect is also achieved that the refrigerant does not flow through the throughflow devices of a heat exchanger unit at substantially the same time, but rather section by section, with the sections being determined by the separating devices. This enables a more uniform cooling of the circulating medium to be achieved over the entire area of the throughflow devices.

Furthermore, it is also possible for a plurality of separating devices and/or a plurality of throughflow devices to be provided in order to achieve the effect that medium will flow through the apparatus or the heat exchanger units in a plurality of sections. A relatively large number of flow connection devices may also be used to arrange more than two heat exchanger units one behind another.